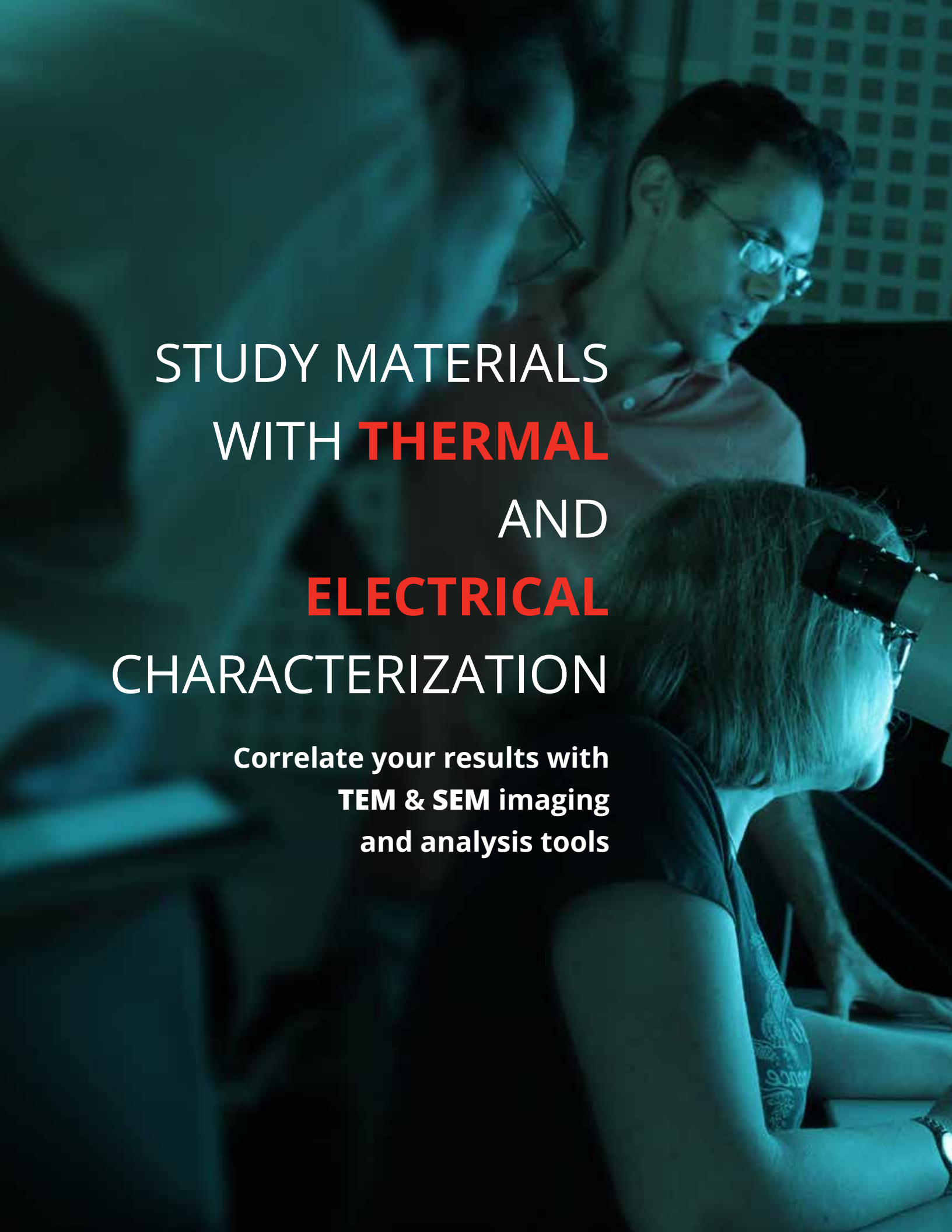
FUSION

IN SITU HEATING AND ELECTRICAL

Protochips



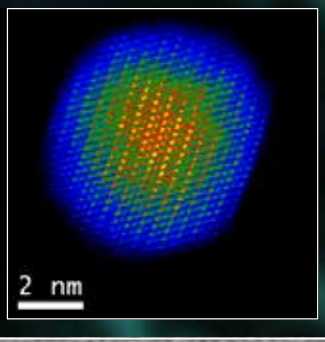
STUDY MATERIALS WITH **THERMAL** AND **ELECTRICAL** CHARACTERIZATION

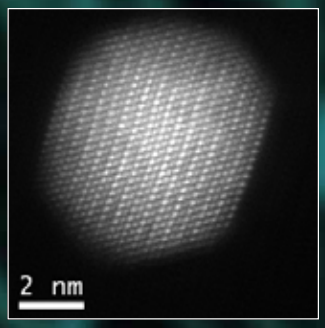
Correlate your results with TEM & SEM imaging and analysis tools

PtCo Nanoparticle

700 °C

Image courtesy Oak Ridge National Lab

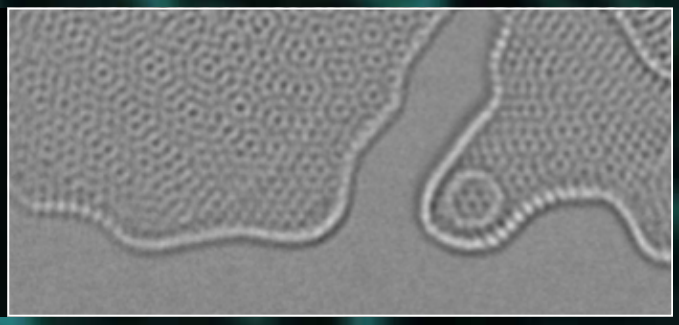




Fullerene

1200 °C

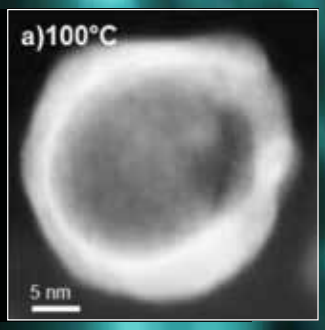
Image courtesy CIC nanoGUNE

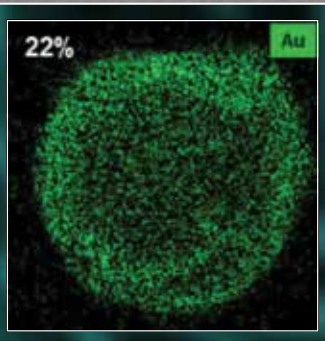


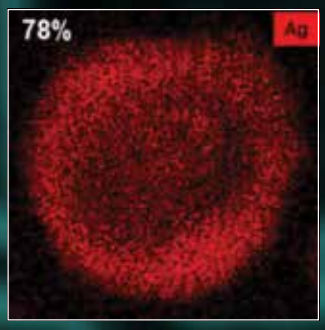
AuAg Nanoparticles

EDS, 400 °C

Image courtesy University of Manchester



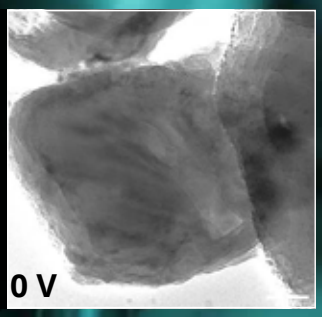


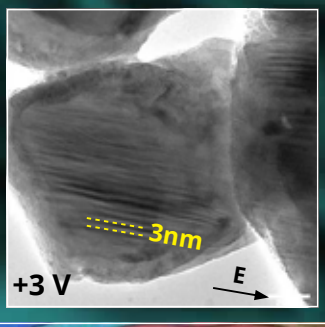


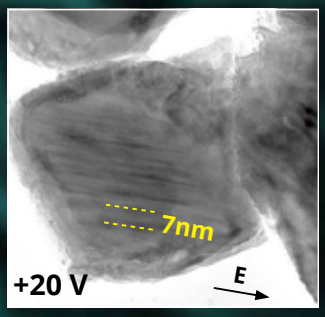
Ferroelectric Nanoparticles

700 °C

Image courtesy Dr. Matias Acosta







Au on Ti

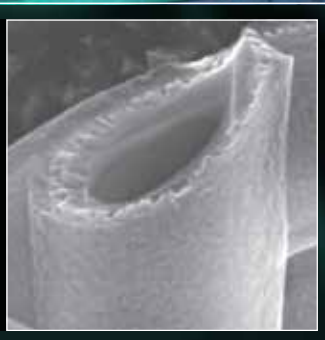
EBSD

Image courtesy JEOL USA

ZnO/Al_2O_3 Fibers

750 °C

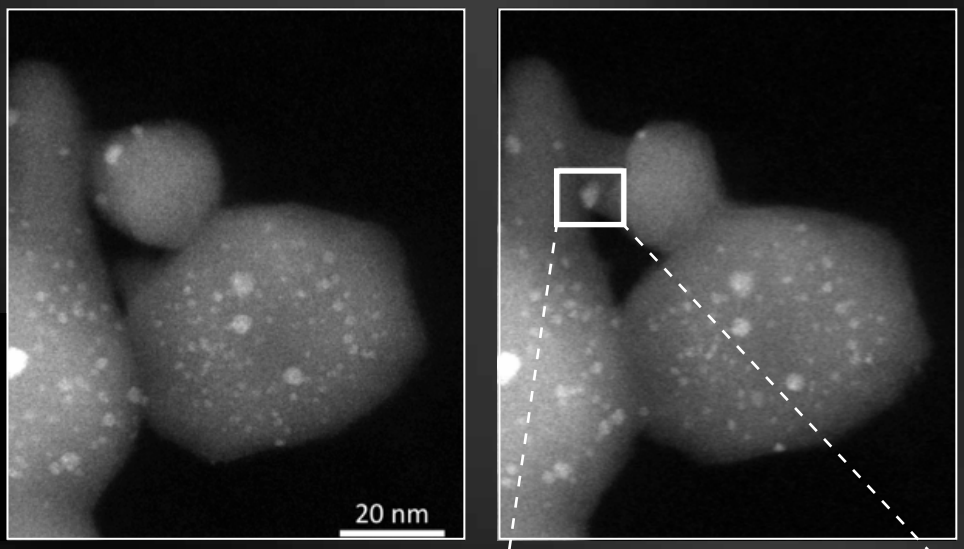
Image courtesy Dr. Hessam Ghassemi



WATCH
DYNAMIC
CHANGES

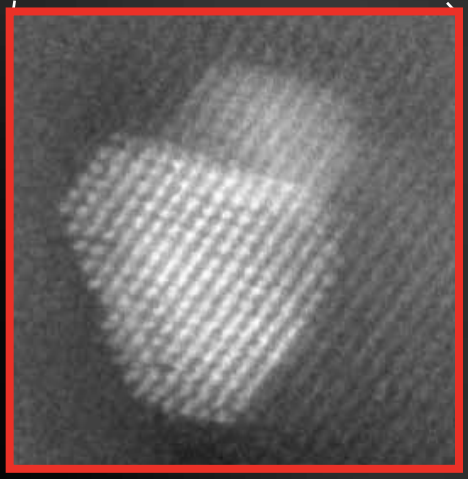
600 °C

700 °C



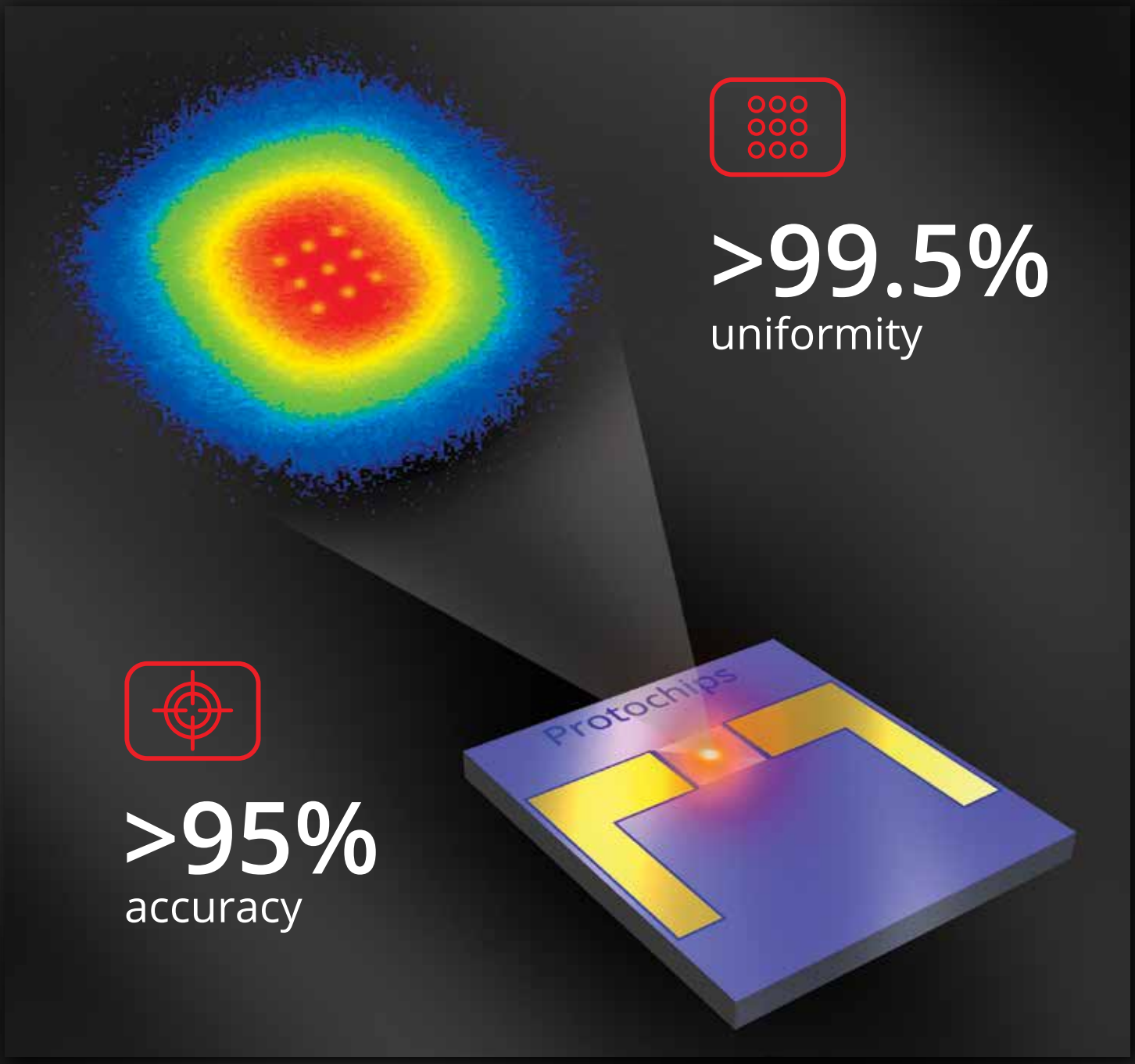
Au on Fe_2O_3
600 °C – 700 °C
Image courtesy Oak Ridge National Lab

ACHIEVE
HIGH
RESOLUTION



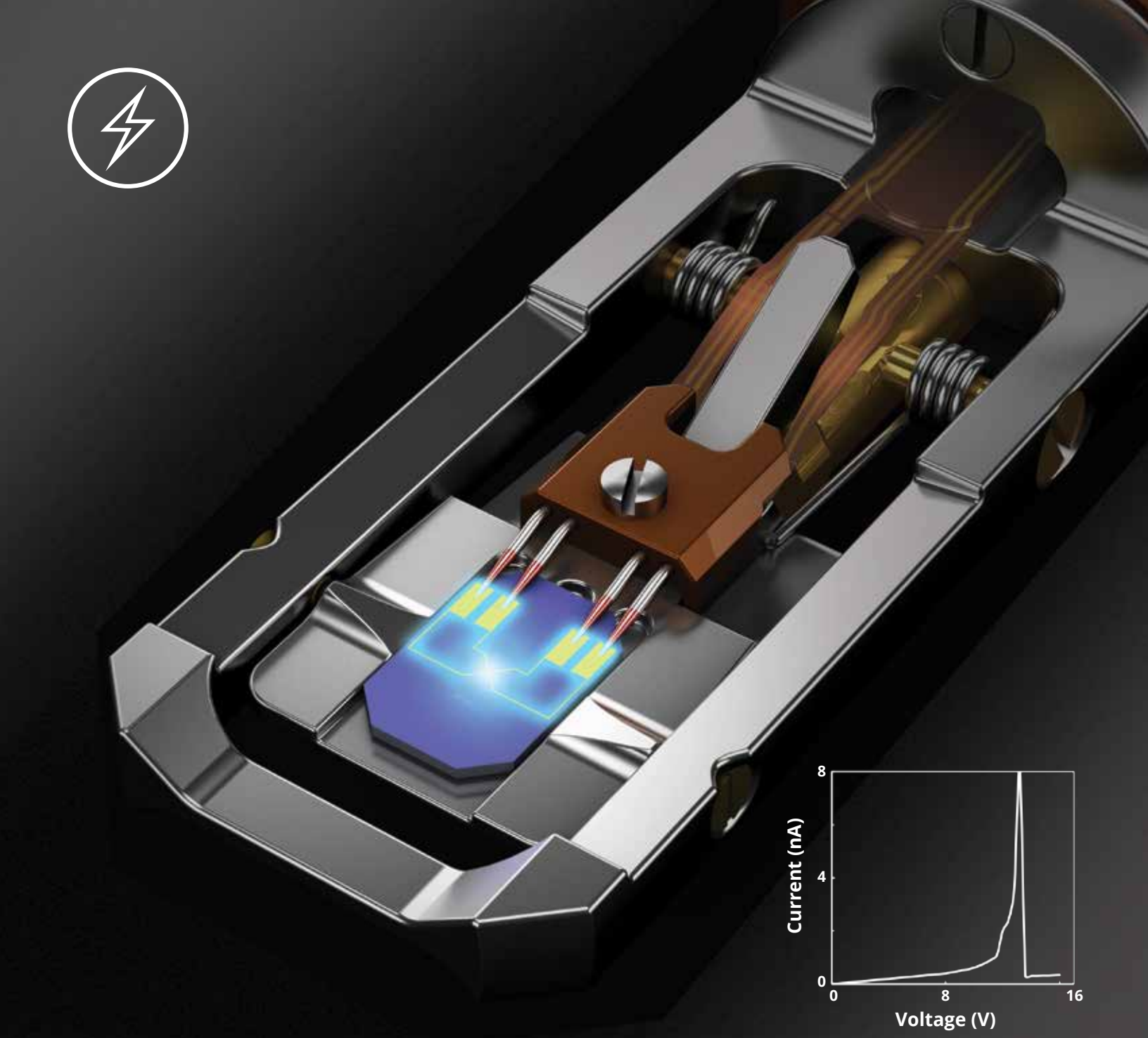
SETTLES FAST with minimal displacement

Fusion combines a new low-power E-chip™ technology with holders constructed using special alloys to dissipate heat. The result is minimal displacement and drift during heating experiments. With only nanometers of displacement during changes of hundreds of degrees, easily follow your area of interest even at the highest magnifications when heating and quenching your sample.



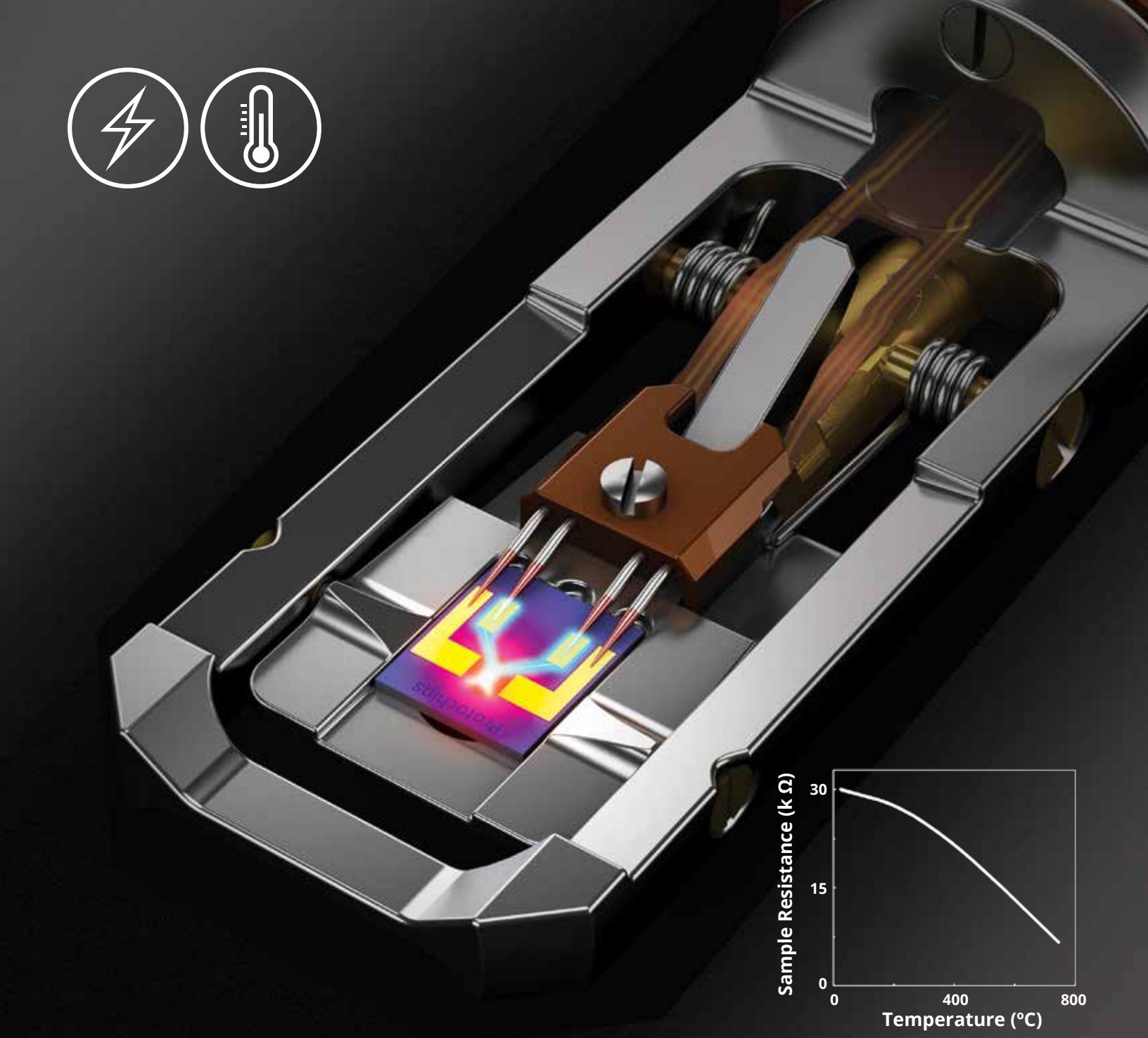
ACCURACY & UNIFORMITY everywhere you image

Temperature accuracy starts with thermal uniformity. A non-uniform heating surface is not at a single temperature, therefore knowing the precise temperature of your sample is nearly impossible. Fusion's proprietary ceramic heating technology integrates the heater and the sample support area into a single thin film with temperature uniformity better than 99.5%.



ELECTRICAL characterization

The fundamental challenge facing electrical experiments in the TEM or SEM is the very low current required to characterize nanoscale samples. These currents are often less than a nanoamp and must be precisely sourced and measured on a low-parasitic sample support to ensure accurate results. Fusion is a fully featured system that provides single digit picoamp measurements with sensitivity into the attoamps. With over 30 different electrical E- chip variations, there is a sample support for every application.



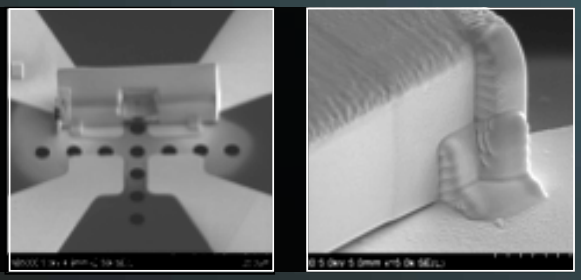
ELECTROTHERMAL characterization

Until now, it has been impossible to observe and measure electrical properties as a function of temperature inside an electron microscope. Electrothermal E- chips feature a silicon carbide heater with tungsten electrodes that enable researchers to perform these experiments even at high temperatures. The electrothermal function combines the full features and specifications of the Fusion heating and electrical modes into a single easy-to-use software interface.

SOFTWARE CONTROL with image synchronization

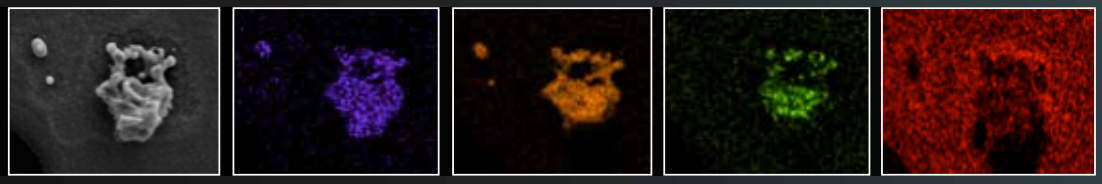
Control your experiments with powerful, intuitive Clarity™ software. Program electrical and/or thermal stimuli as waveforms or change parameters as you go. Observe data in real time with a visual user interface that plots your results. Optional ImageSync™ software synchronizes images and video with the heating and electrical data, so analyzing your results is fast and easy.

ATTACH FIB LAMELLA
for thermal & electrical characterization in SEM or TEM



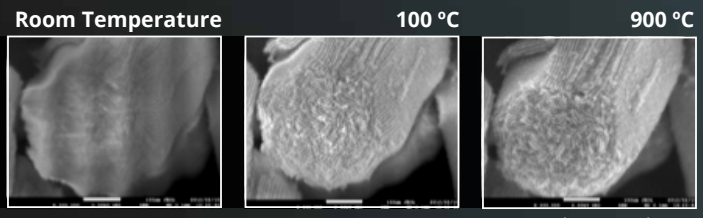
Semiconductor FIB lamella on E-chip

EDS MAP
material transformations



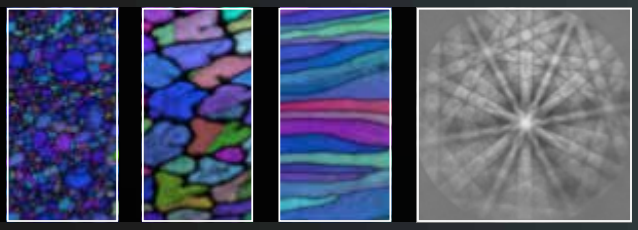
Limestone heated to 1000°C then quenched

ELIMINATE CHARGING
on insulating materials by applying temperature



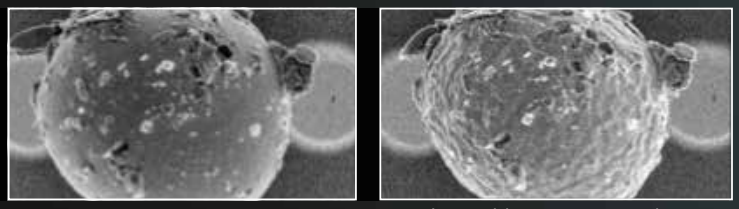
Mesoporous Silica (insulator)

EBSD
phase transformation and recrystallization



Thermal grain growth of gold

HEAT & QUENCH
up to 70 microns in size



Molten solder - 20 micron diameter

SEM thermal & electrical characterization

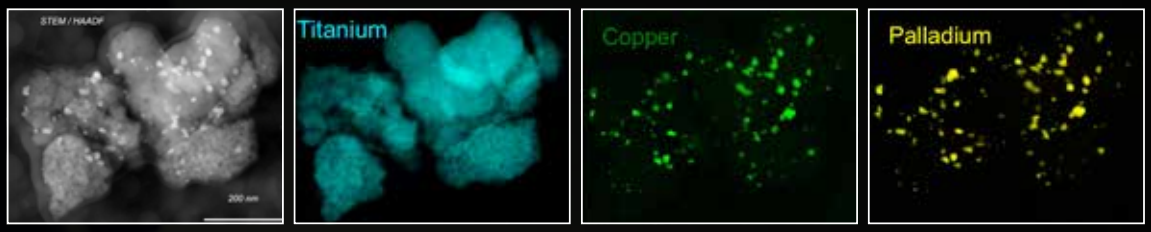
The same E-chip supports for the TEM can be used in an SEM with the Fusion SEM holder. Correlative experiments in the SEM enable analysis of morphology and composition using SE and BSE analysis. Together, the SEM and TEM are the perfect combination to analyze samples and correlate data to form a complete picture of material properties.

TEM PRODUCTS THAT ARE **SAFE** AND **COMPATIBLE** WITH YOUR **MICROSCOPE**

Carefully evaluated and approved by your instrument manufacturer

EDS ANALYSIS

EDS analysis is fundamental to in situ materials research. By collaborating closely with the microscope manufacturers, all Fusion holders are optimized to maximize the collection of EDS signals, even at zero alpha tilt.



Pd on TiO_2
EDS, 500 °C:
Image courtesy Argonne National Lab

DOUBLE TILT

Smooth alpha and beta tilting and variable-speed finger touch controls enable precise, stable holder positioning. The E-Chip and the electrical contacts tilt together during beta tilt, providing excellent mechanical and electrical stability, while touch detection controls ensure microscope safety.

"The Protochips system was integral to the success of the experiments. Repeatable image stability during heating with minimal sample drift allowed reliable acquisition of electron holograms. The steady heating and cooling rates enabled consistent repeatable experiments, which otherwise would have influenced the thermomagnetic behavior."

- Dr. Trevor Almeida, University of Glasgow

"For the first time I can now simultaneously heat and apply an electric field to my sample within the electron microscope. With this system I can observe the dynamic processes and mechanisms of field assisted sintering as they occur."

- Dr. Klaus Van Bentham, University of California, Davis

140 Over 140 scientific peer-reviewed journal articles

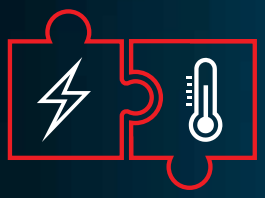
150 Over 150 heating systems in the market

1300 Over 1300 citations

"Our in situ work required a very stable double-tilt heating system to obtain atomic resolution of on-axis images while applying temperature changes to the sample. Without the Protochips heating system, our results would not have been possible."

- Dr. James LeBeau, North Carolina State University

ONE SYSTEM, **ENDLESS POSSIBILITIES**



FUSION SPECIFICATIONS

TEM HOLDERS

Microscopes	Most Manufacturers and Models
Compatibility	EDS, EELS, STEM, Diffraction, ETEM, Raman, Holography
Alpha Tilt	Up to ± 55° (varies by model)
Beta Tilt (Option)	± 10°

SEM HOLDERS

Microscopes	Most Manufacturers and Models
Compatibility	SE, BSE, EDS, EBSD, STEM, Raman
Loading	Load Lock & Direct Mounting

HEATING

Max Temperature*	1200 °C (900 °C for Electrothermal)
Temperature Uniformity	> 99.5%
Temperature Accuracy	> 95%
Temp Stability	< 0.01 ºC
Heating & Cooling Rate	Any rate up to 1000 ºC/ms
Low Displacement	7 nm at 5 seconds with 325 °C ΔT
Sample Supports	Through Hole - Silicon Nitride - Holey Carbon
Max Resolution	0.6 Å
Ultimate Drift Rate	0.5 nm/minute
Interchangeable E-Chips	Interchangeable E-chips | Between all TEM and SEM holders

ELECTRICAL

Max Current	100 mA
Max Voltage	55 V, inquire for higher
Max Electric Field	Up to 100 kV/cm
AC	Low Frequency
E-Chip Configurations	30
E-Chips	Interchangeable E-chips | Between all TEM and SEM holders
Current Measurement Accuracy	± 0.15% + 750 fA
Voltage Measurement Accuracy	± 0.015% + 225 µV

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Quantifiably Better™

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